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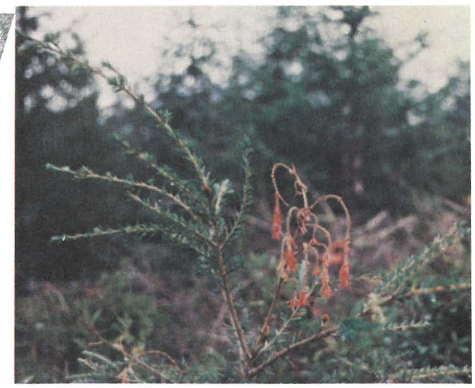

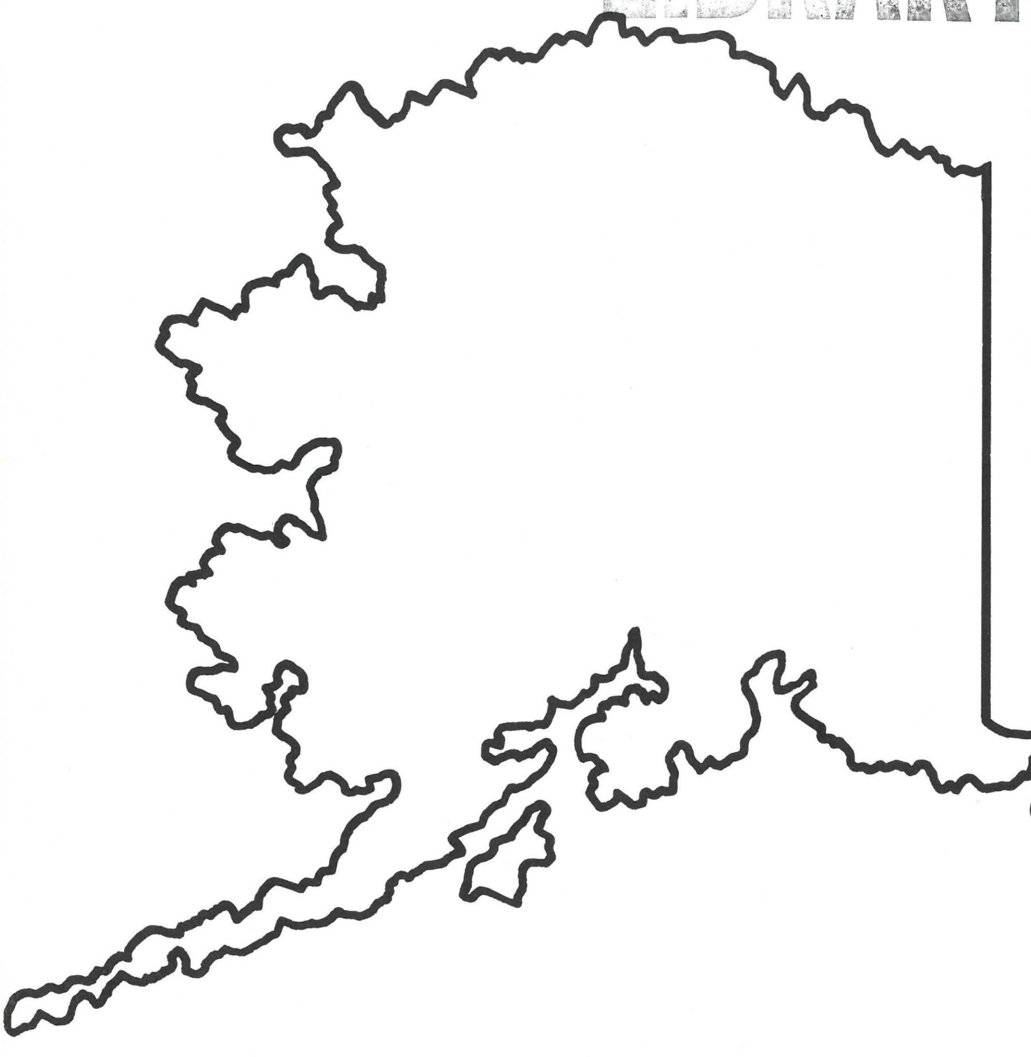

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CONTENTS

RESEARCH SUMMARY

Clearcut areas regenerated to western hemlock and Sitka spruce in southeast Alaska were surveyed for damage by Sirococcus shoot blight. A disease index was calculated for potential crop trees. All Western hemlock regeneration was infected. Disease severity was greater in suppressed and intermediate than in dominant and codominant crown classes. Mortality and severe top-killing were restricted to suppressed and intermediate crown classes. Disease severity was greater in lower than in the upper crown of potential crop trees. Terminal leader kill in potential crop trees was common. Direct measures of disease control are not recommended.

INTRODUCTION

Shoot blight of western hemlock [*Tsuga heterophylla* (Rafn.) Sarg.] regeneration in southeast Alaska (fig. 1) was observed first in 1967 on the mainland, 12 mi NNE of Petersburg at Thomas Bay (Baker and Laurent 1974). Funk (1972) identified the causal agent as *Sirococcus strobilinus* Preuss. He demonstrated its pathogenicity by inoculating young trees and reisolation from diseased tissues. Since its discovery, the disease has been closely monitored by Insect and Disease Control and Timber Management personnel of the Alaska Region (Baker and Curtis 1973; Baker and Laurent 1974; Baker and others 1975; Crosby and Curtis 1968, 1970; Curtis and Swanson 1972; Hostetler and others 1976). The disease is spreading. It is now known to occur at several locations in southeast Alaska as far north as Juneau. A high intensity of infection continues to exist at Thomas Bay. In 1972, Sitka spruce [*Picea sitchensis* (Bong.) Carr.] regeneration also was observed to be affected by the disease (Baker and Curtis 1973).

Sirococcus shoot blight of conifer seedlings and saplings is known to occur in many areas of the world. Little information is available concerning its potential to damage natural regeneration (Graves 1914; Kujala 1950; Lagerberg 1933; O'Brien 1973; Robak 1956). This report presents quantitative data of damage caused by *S. strobilinus* to western hemlock regeneration at Thomas Bay, Alaska. Significance of this damage to future management of these young stands is discussed.

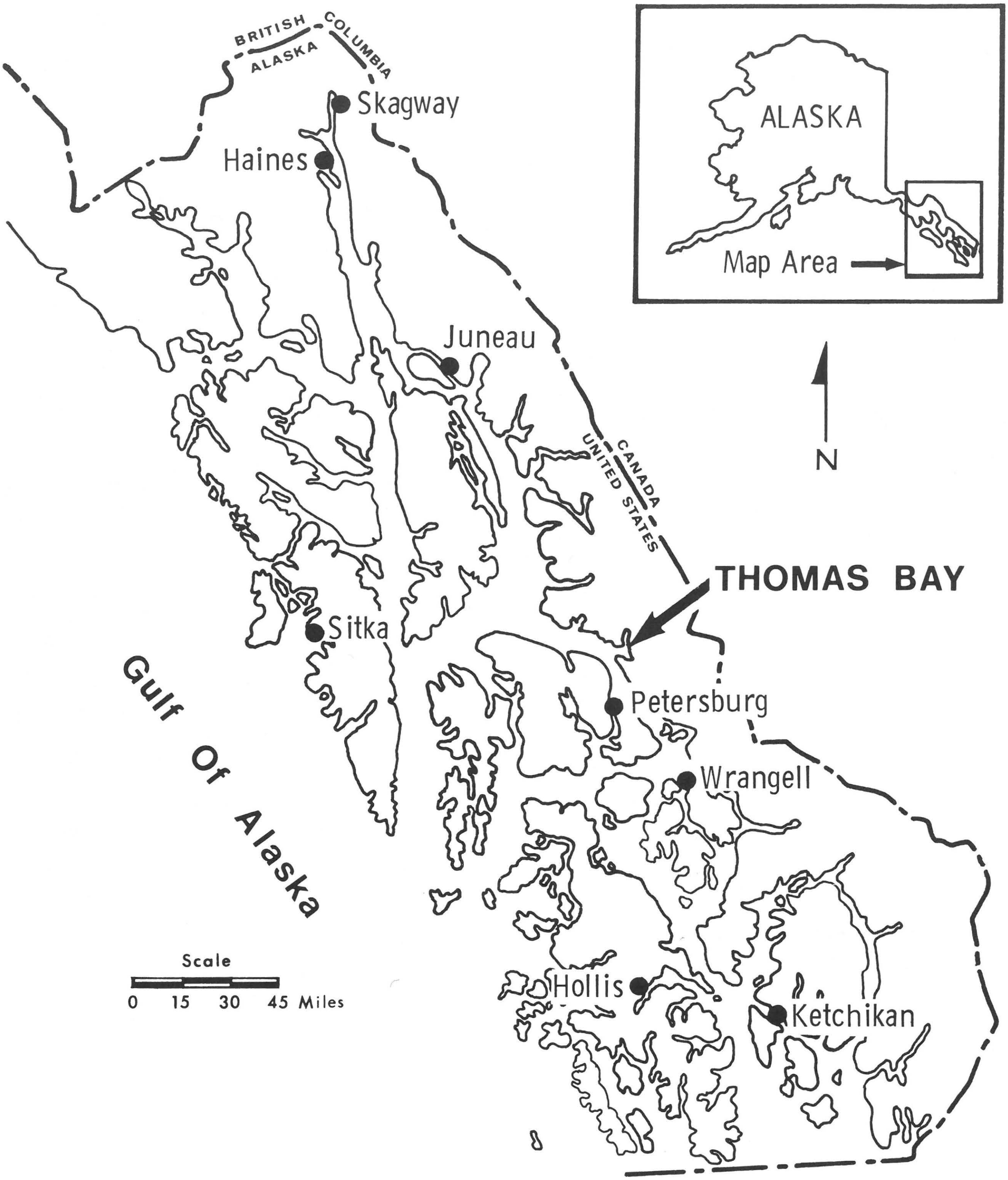

Figure 1.--Map of southeastern Alaska. Sirococcus *shoot blight was discovered at Thomas Bay in 1967, has now spread north to Juneau.*

MATERIALS AND METHODS

Four clearcut areas, supporting natural regeneration of western hemlock and Sitka spruce less than 20 years old, were sampled. Areas were selected on the basis of comparable age, stand origin, macroclimate, and documented occurrence of *S. strobilinus*. Clearcuts were from 0.2 to 0.5 mi apart and all on recent glacial outwash. One of the four areas had been thinned; the other three were unthinned.

The three unthinned areas had been clearcut in 1959-1962, so the oldest regeneration was 16 years. One of these areas had received 464 kg Agricultural Grade urea/hectare in May 1969; the two remaining areas were untreated. A line of 4 plots, 100 m apart and 4 m^2 area, was established in each of the three areas. Total number of (1) trees, (2) infected trees, (3) dead trees, and (4) potential crop trees (dominants or codominants) were recorded for each plot.

Five potential crop trees were selected from each plot for second-order sampling. These trees were cut at ground line and removed from the plot. Total height, total number of branches, and year of dead terminal leader (6 years accumulation) were recorded for each tree. Six primary branches (two lower, two middle, and two upper crown) were removed from each tree and used for third-order sampling. Total length of primary, secondary, tertiary, etc., branching and total length of branching with symptoms of *Sirococcus* infection were recorded for each primary branch sampled. The ratio of infected branch length:total branch length for the tree was calculated and used as a disease index. An analysis of variance was conducted for the disease index data from the three unthinned areas, using the following model for an unbalanced design (Snedecor 1959):

$$Y = \mu + \gamma_i + \alpha_{j(i)} + \Sigma_{ijk}$$

where

Y = dependent variable

μ = mean

γ_i = treatment

$\alpha_{j(i)}$ = plot nested in treatment

Σ_{ijk} = error

The fourth area sampled was a 0.4 ha plot that was mechanically thinned in 1975 to a 2.4 × 2.4 m spacing. Maximum age of the regeneration was 20 years. Twelve western hemlock trees, comparable in size, were selected from the plot and sampled in the same manner as those from the previous three areas. The disease index data were not included in the analysis of variance because the severely infected western hemlock was removed during the recent thinning and Sitka spruce was favored in selection of crop trees.

RESULTS

Unthinned areas.--The three areas examined were overstocked (table 1). More than 90 percent of the conifer regeneration was western hemlock. The remaining conifer regeneration was Sitka spruce. Considerable amounts of broad-leaf shrubs also occupied the sites.

All the western hemlock regeneration was infected by *S. strobilinus* (fig. 2). Infection was most severe on regeneration in the suppressed and intermediate crown classes. Some of this regeneration showed severe top-killing (table 1) and a bushy, broomlike growth form with no definitive terminal leader (fig. 3). It is likely that earlier in the life of the stand, many of these individuals were dominants and codominants; the disease cost them their dominant position. All mortality attributed to the disease (table 1) was in the suppressed and intermediate crown classes.

Recent (1975 and 1976) leader kill in potential crop trees (fig. 4) was common. The accumulative leader kill over a 6-year period was high (table 2). No mortality or severe top-kill (fig. 3) was recorded for potential crop trees. Disease was more severe in the lower crowns and least in the upper crowns in all trees examined.

Analysis of variance showed a significant difference (P=0.05) in disease index between areas and plots. We believe these differences are related to local environmental factors not measured during the study (Wall and Magasi 1976).

No infection of Sitka spruce was recorded on the plots examined. However, while moving from plot to plot, an occasional infected Sitka spruce (fig. 5) was observed.

Table 1.--*Stocking, infection, and mortality data/hectare for western hemlock and Sitka spruce regeneration, Thomas Bay, Alaska*

Area	Total trees[1]	Crop trees[1]	Infected trees[2]	Dead trees[3]	Top-killed trees
	No.	*Percent*			
1	59,500	23.1	93.7	10.5	13.4
2	86,250	18.8	91.9	12.2	34.8
3[4]	55,000	32.7	90.9	21.4	20.5
4[5]	1,663	100.0	100.0		

[1]Includes Sitka spruce.
[2]Represents 100 percent of western hemlock.
[3]All were in the intermediate and suppressed crown classes.
[4]Fertilized May 1969; 464 kg Agricultural Grade urea/hectare.
[5]Area thinned in 1975 to 2.4 × 2.4 m spacing.

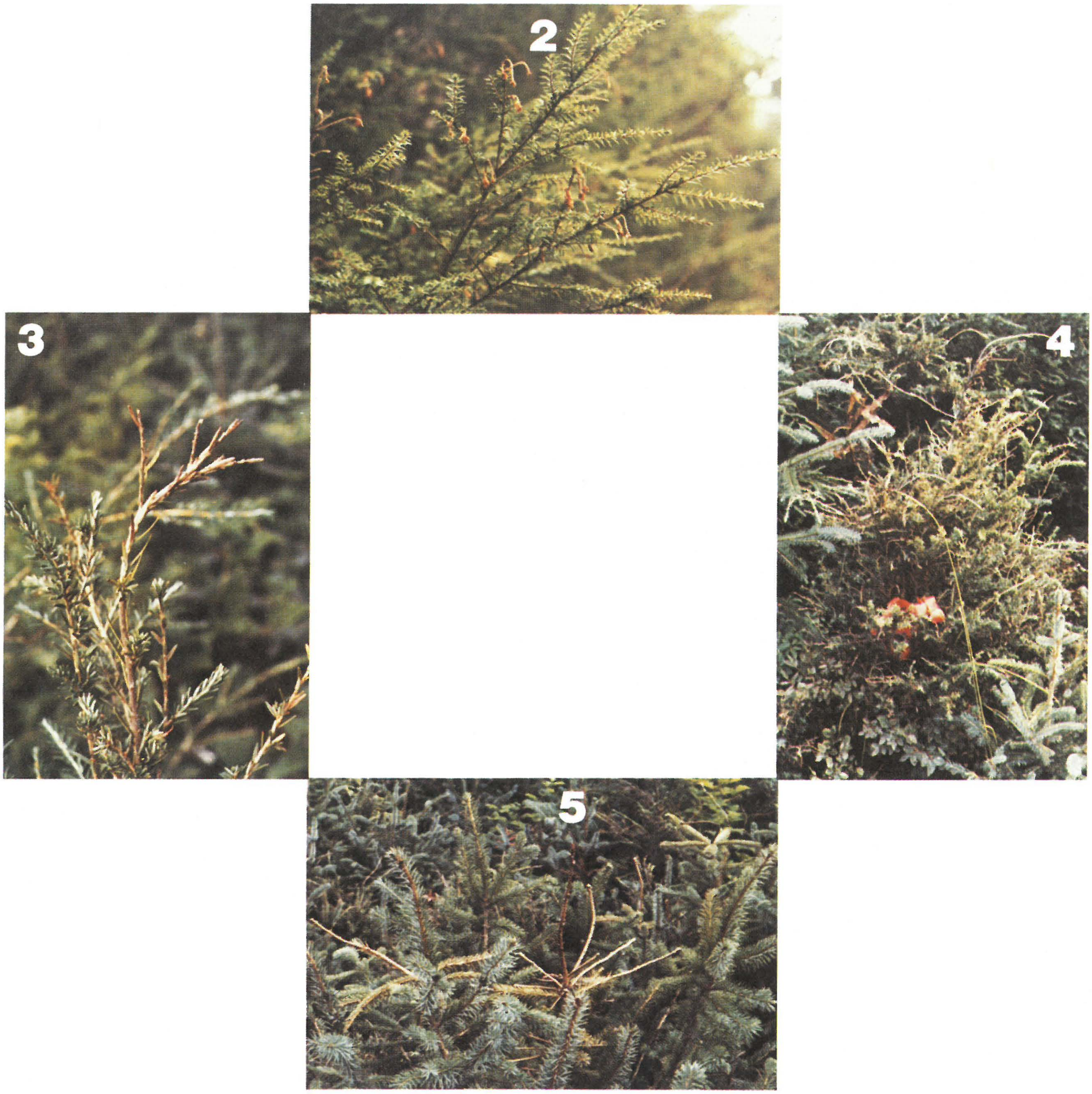

Figure 2.--Young shoots of western hemlock killed by Sirococcus strobilinus. *3.--Severe shoot blight damage of suppressed regeneration. 4.--Terminal kill by* Sirococcus strobilinus. *5.-- Shoot blight damage of Sitka spruce.*

Table 2.--*Mean growth and shoot-blight infection data for potential crop trees in western hemlock regeneration, Thomas Bay, Alaska*

Area	Height	Total branching	Dead branching	Disease index[1]	Terminal killed[2]
	- - - - - - - - *Meters*	- - - - - - - - -			*Percent*
1	2.96	398.1	36.2	0.091 a	63.2
2	2.64	224.6	31.7	.141 b	80.0
3[3]	2.81	326.0	61.0	.187 c	75.0
4[4]	4.16	680.0	54.9	.081	42.0

[1]Means followed by a different letter are significantly different ($p=0.05$; Duncan Multiple Range Test). Area No. 4 not included in analyses.
[2]Accumulative for 1971-1976.
[3]Fertilized May 1969; 464 kg Agricultural Grade urea/hectare.
[4]Thinned in 1975 to 2.4 × 2.4 m spacing.

Thinned area.--Thinning was accomplished only 15 months prior to the disease survey. Therefore, comparisons between the thinned and unthinned areas must be conditioned. The average potential crop tree was larger on the thinned area than on the unthinned areas (table 2) because it was 4 years older and largest trees were selected as crop trees. Disease index and percentage terminal kill were lower than on the unthinned areas (table 2) because severely infected trees were removed during the thinning. These data indicate good quality control in the selection of crop trees during the thinning operation. The ratio of Sitka spruce to western hemlock is higher in the thinned than in the unthinned areas. This was intended since Sitka spruce was favored in leave tree selection.

Fertilized vs. nonfertilized areas.--The fertilized area had the lowest overall stocking of the unthinned areas (table 1). However, the number of potential crop trees was much higher than on the nonfertilized areas. Percentage dead trees in the suppressed and intermediate crown classes was twice that of the nonfertilized areas. Percentage top-kill trees in these crown classes was intermediate between the two nonfertilized areas. Disease index for potential crop trees on the fertilized area was the highest of all areas examined (table 2).

DISCUSSION

Western hemlock is a climax species. It is very tolerant of shade and well adapted to growth as a crowded, suppressed understory in areas of high precipitation. Development of *Sirococcus* shoot blight is favored by conditions of high atmospheric moisture, mild temperatures, and low light intensities (Funk 1972; Peterson and Smith 1975; Smith 1973). Spores of the causal fungus are disseminated by splashing of water drops (Peterson and Smith 1975). The spores infect only juvenile needles and the disease kills new shoots (Peterson and Smith 1975). Such environmental requirements explain why disease severity is greater in regeneration of suppressed and intermediate crown classes than in potential crop trees. Environments of overstocked western hemlock forest ecosystems in southeast Alaska are ideal for optimum development of the suscept and the disease.

The highest disease index was 0.187 for the fertilized area. This means that 18.7 percent of the branching has been killed by the disease. Unfortunately, there was no opportunity during this investigation to sample a comparable area of western hemlock regeneration that was disease-free. Neither can we find published data adequate for quantitative comparisons. Therefore, we cannot express the disease index in quantitative terms of growth reduction.

Sirococcus shoot blight reduces tree growth because it reduces photosynthetic tissue and causes a net loss in carbohydrates. Food for tree growth is produced by active photosynthesis or may come from stored reserves. Young conifer needles are more efficient in photosynthesis than are older ones. Likewise, branches in the upper crown exposed to full sunlight are more efficient than those in the lower crown. Branches in the partially shaded lower crown may not produce enough food to maintain their growth. In some conifers, little or no additional food is translocated to these branches and they die. This process, called natural pruning, is very common in shade-intolerant species. In other conifers, food manufactured in other parts of the crown is translocated to branches inefficient in photosynthesis, and they remain alive. Such branches are parasitic on the tree and natural pruning is minimal. Therefore, comparisons of the effects of foliage removal by artificial or natural pruning from below with equal amounts of defoliation by a foliage disease are not valid. *Sirococcus* shoot blight is selective. It kills those tissues most efficient in photosynthesis; young needles.

When photosynthetic tissue and carbohydrate losses are so great that active photosynthesis cannot supply the food necessary for growth, then it must come from stored reserves. When this condition persists for a time sufficient to deplete these reserves, tree death is eminent. Levels of mortality and severe top-killing (table 1) of regeneration in suppressed and intermediate crown classes signify that the above condition prevails in these crown classes.

In view of current stocking levels, we consider the above condition as beneficial to management of the areas for timber production. Trees in suppressed and intermediate crown classes represent surplus stocking (table 1). Their presence provides undesirable competition for potential crop trees. The disease is effecting a natural thinning in these crown classes. This will reduce competition and enhance growth and dominance of potential crop trees. Unfortunately, the rate of natural thinning is inadequate for optimal growth release.

The disease situation in potential crop trees is very different from that recorded for suppressed and intermediate crown classes. No mortality or severe top-killing was recorded. Disease damage was much greater in shaded, lower portions of crowns than in upper crowns. Although periodic terminal leader kill has reduced total height, it has not caused any major stem deformity. Such damage can be detected only by closeup, detailed examination of upper stems. Leader kill occurring more than 6 years ago is no longer discernible. Normal growth form has not been altered.

The greatest differences between the fertilized and nonfertilized areas were in mortality and percentage of potential crop trees. The slight reduction in stocking level of the fertilized area can be explained by a higher mortality level (table 1). Our sampling was not adequate to estimate the total variation in disease severity within and between the unthinned areas. We believe the higher percentage of potential crop trees in the fertilized area is a direct result of the fertilizer treatment. The additional nutrients enhanced growth of the seedlings and permitted a greater number to express dominance earlier. The high density of dominants and codominants created environmental conditions, within these crown classes, more favorable for infection and disease development. The result was a higher disease index for potential crop trees in the fertilized area.

CONCLUSIONS AND RECOMMENDATIONS

We conclude that the current level of *Sirococcus* blight in potential crop trees in southeast Alaska is no cause for alarm. This conclusion is based on our data and knowledge of the suscept and the disease. We believe the disease to be native to the area. Infections were found in western hemlock more than 300 years old. The disease is not restricted to young regeneration, but it is more noticeable in this material. No direct disease control measures are recommended at this time (Smith and others 1972). Monitoring of the disease in southeast Alaska should continue.

Sirococcus strobilinus is reducing height growth of western hemlock by killing the terminal leaders. However, competition is the major cause of growth reduction in areas surveyed at Thomas Bay. The regeneration is over 15 years old and dominance has been expressed. We recommend that Timber Management personnel thin these stands to stocking levels established for the Alaska Region. This will not only enhance growth of selected crop trees, but will create environments less favorable for development of *Sirococcus* shoot blight. The mixture of western hemlock and Sitka spruce should be maintained in a reasonable facsimile of their natural ratio.

The unthinned areas illustrate some adverse effects of overstocking. We conclude that the fertilizer treatment prior to thinning has compounded these adverse effects. We recommend that future applications of fertilizer be made after, not prior to, thinning. This will ensure that increased growth will be concentrated on those stems selected for future crop trees.

Establishment of nurseries in southeast Alaska for production of western hemlock planting stock would be a high risk adventure. *Sirococcus strobilinus* is capable of causing severe losses in nurseries because the environment usually favors development of disease. If western hemlock planting stock is needed, we would recommend production by containerized methods in greenhouses. A subirrigating system, a forced-air ventilation system, and a supplemental lighting system would be required to maintain a relatively blight-free environment.

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